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Study on the Thermal Degradation Kinetics of the Common Wooden Boards

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Abstract

The thermal degradation behaviors and kinetics of five common wooden boards were studied by TG-DTG techniques at different heating rates 10K/min, 15K/min, 20K/min, 25K/min and 30K/min in air atmosphere. The kinetic parameters, activation energy, of the degradation process for the wooden boards were calculated by means of Kissinger and Coats-Redfern methods. The results show that the whole course of pyrolysis of the five wooden boards can be divided into three phases and the main stage's activation energy of core-boards is the highest. It also shows that the results of Kissinger method are higher than Coats-Redfern's. The causes of the differences between the two methods and the probable factors causing errors during the experiment are also discussed.

Keywords: wooden boards; pyrolysis; thermogravimetric analysis; reaction kinetics

Nomenclature

A	pre-exponential factor(min-1)
E	apparent activation energy(kJ/mol)
$f(\alpha)$	reacting mechanism function
k	reaction rate constant
m	remaining sample weight (kg)
m_0	initial sample weight(kg)
m_∞	final sample weight(kg)
R	gas constant
t	time(s)
T	absolute temperature(K)
T_{pi}	temperature at the maximum weight loss(K)
Greek symbols	
α	the extent of conversion of decomposed solid at time t
β	heating rate constant (K/min)

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1. Introduction

Wooden boards, with its characteristics of small density, easy processing and good durability [1], are widely used in all kinds of construction and interior decoration. With the development of the processing technology, after physical or chemical reform, more and more processed wooden boards are gradually replacing wood raw materials. Thus they become the main fire loads in buildings. Because of the different properties of different wooden boards, studies on the thermal degradation procedures in the fire are of instructive significance to analyse fire's occurrence and evolution.

Domestic researchers mainly studied different kinds of log sheets, using the thermal analysis instruments to analyse the similarities and differences between the characteristic curves under different experimental conditions which can be used to study the effects of experimental conditions. Theyanalysed the pyrolysis process of samples using a kinetic model of one-dimensional diffusion [2]. Foreign scholars mainly studied the kinetic response model and the calculation of kinetic parameters. Kissinger in 1957 studied the chemical reaction kinetics in DTA when $f(\alpha)=(1-\alpha)^n$, where n is reaction order. He published an article in American Analytical Chemistry, named Reaction Kinetics in Differential Thermal Analysis, and established the famous Kissinger equation.

Using TG and DTG methods, the thesis analyzes the pyrolysis kinetics processes of five kinds of common wooden boards under air atmosphere [3], they are density board, core-board, particle board, plywood and pine board. By comparing the curves and data, we conclude the similarities and differences of thermal changes among different wooden boards under a non-isothermal condition at high temperatures. And by using Kissinger and Coats-redfern methods respectively, we calculate the kinetic parameters and further summarize the pyrolysis characteristics of five kinds of wooden boards. The statistics above provide some reference when the fire investigatioin department uses thermoanalysis technology for evidence identification in fire scene.

2. Experimental

2.1. Materials

Five kinds of wooden boards are chosen in the experiment. They are density board, core-board, particle board, plywood and pine board.

2.2. Apparatus and conditions

The TG and DTG analysis for the wooden boards were conducted on a TGA/SDTA851e type thermal analyzer under the following conditions:

- atmosphere: air as reactive gas at a flow rate of 30ml/min; pure nitrogen as protective gas at a flow rate of 30ml/min;
- sample mass: 4~5mg;
- heating rate:β=10, 15, 20, 25, 30K/min;
- temperature range: from 50℃ to 700℃;
- reference material:Al_2O_3.

2.3. Kinetic methods

Differential and integral methods are usually used to calculate the kinetic parameters. Differentiation provides kinetic parameters by using a series of given points using local data [4] while integration refers to the overall data within which the kinetic parameters are provided by the integral value.

The pyrolysis kinetics generally assumes that under adiabatic condition

$$\frac{d\alpha}{dt}=kf(\alpha) \tag{1}$$

where, for TG the extent of conversion is $\alpha=\frac{m_0-m}{m_0-m_\infty}$ and heating rate is $\beta=\frac{dT}{dt}$.

Thus Eq. (1) changes to the following form:

$$\frac{d\alpha}{dT}=\beta\frac{d\alpha}{dt}=\beta kf(\alpha) \tag{2}$$

According to the Arrhenius equation:

$$k=A\exp(-\frac{E}{RT}) \tag{3}$$